Energy Policy 123 (2018) 198–207

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

The effect of Peru's CDM investments on households' welfare: An econometric approach

Nicolas Pécastaing*, Jorge Dávalos, Andy Inga

Universidad del Pacífico, Av. Salaverry 2020 Jesús María, Lima 11, Perú

ARTICLE INFO

JEL classification:
O1
C33
Q56

Keywords:
Climate change
Clean Development Mechanism (CDM)
Poverty
Sustainable development
Panel econometrics

ABSTRACT

The Clean Development Mechanism (CDM) under the Kyoto Protocol has two main objectives: Reducing emissions of greenhouse gases (GHGs) and contributing to sustainable development (SD) in developing countries. The empirical evidence indicates that the first goal has been fulfilled; however, the literature mostly provides ex-ante evidence regarding the second goal. This paper contributes to the literature by assessing the ex-post quantitative effect that CDM projects have had on SD (employment and monetary welfare) in Peru, a country ranked among the most important CDM investment host countries worldwide. The econometric model estimates the direct and indirect effects of the CDM projects' investments on Peruvian households' monetary welfare for 2011–2015. Our results suggest that CDM investments had a slight effect on household consumption expenditure and had no effect neither on employment nor in poverty alleviation. Our findings suggest the need to strengthen CDM's institutional framework by identifying key development definitions and indicators.

1. Introduction

In the context of the Kyoto Protocol, the Clean Development Mechanism (CDM) has made it possible for countries of the Global South to become and remain actively involved participants in the struggle against climate change. One objective of the CDM is to encourage technological transfer, thereby taking part in the sustainable development (SD) of countries that have instituted such projects; another is to allow the business sector of *Annex 1* countries[1] – i.e., countries that have quantifiable reduction emission objectives – to prioritise investment in energy projects (solar, wind, hydro, biomass) of developing countries. As of May 2017, there were officially 7770 such projects registered (Fenhann, 2017). This mechanism would allow enterprises to make low-cost investments in *Non-Annex 1* countries to obtain certified reductions in units of emissions (CERs)[2] while simultaneously providing a means by which the Global South can rapidly obtain the environmentally friendly technologies needed to make the transition to greener energies. The value of carbon credits obtained by investors corresponds to the difference between emissions estimated as a result of the implementation of the project and a baseline-emissions scenario previously defined and validated by the CDM Executive Board.

For the CDMs, the Development Objective is, in fact, subject to little oversight in comparison to the numerous verifications, checks, and audits of the emissions' reduction objective. This is largely because investor profits depend on the accuracy of figures on emissions' reductions, specifically the amount of annual Greenhouse gas emissions (GES) reductions (in TCO2e) linked to the project. Even if the contribution of the CDM to the development of the host country has been widely studied in the economic literature, most of these studies have given priority to qualitative ex-ante approaches that assess the "potential" effects of the CDM on the social, economic, and environmental aspects of development. Consequently, there is a lack of ex-post quantitative evidence of the effects of CDM projects in developing countries (Wang et al., 2013). We contribute to fill this gap by studying the Peruvian case, a country whose CDM investments grew rapidly with the registration of 61 projects in May 2017, amounting a total of $4.9 billion. Peru, with its great potential in terms of the development of CDM renewable energy projects (FONAM – Fondo Nacional del Ambiente/National Environmental Fund, 2011) has become a *de facto* specialist in CDM Hydro projects (Fenhann, 2017). The country ranks among the top 3 Latin American countries (LAC) hosting CDM investments (see Fig. 1), while its poverty rate places the country in 7th position (World Bank, 2017).

The main objective of this paper is to identify the depth of the effect

* Corresponding author.
E-mail addresses: n.pecastaing@up.edu.pe (N. Pécastaing), je.davalosc@up.edu.pe (J. Dávalos), am.ingam@up.edu.pe (A. Inga).

[1] *Annex I* countries include "the industrialized countries that were members of the *Organization for Economic Co-operation and Development* (OECD) in 1992"; *Non-Annex I* countries are mostly developing countries. (See the *United Nations framework convention on climate change (UNFCCC)* website: https://unfccc.int).

[2] CERs: Certified emission reductions.

https://doi.org/10.1016/j.enpol.2018.08.047
Received 6 February 2018; Received in revised form 17 August 2018; Accepted 20 August 2018
Available online 05 September 2018
0301-4215/ © 2018 Elsevier Ltd. All rights reserved.

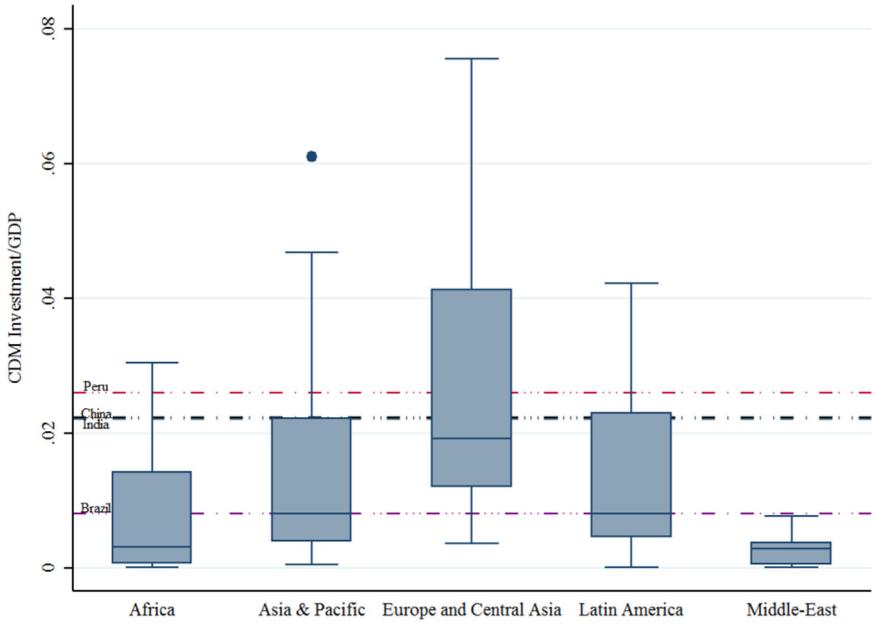

Fig. 1. Share of CDM investments with respect to GDP by regions.
Source: Based on CDM pipeline (Fenhann, 2017).

that CDM investments have had on Peru's monetary welfare and employment. Since poor households are classified as such according to their per capita consumption expenditure, CDM investments must first affect per-capita consumption in order to reduce poverty. We test this transmission channel by measuring the effect on per-capita consumption expenditure, and then, on poverty. Our empirical analysis builds on a database that matches a nationally representative household panel for 2011–2015 (INEI-National Institute of Statistics and Information, 2017) with the CDM Pipeline (Fenhann, 2017). The CDM effects are identified by temporal and regional variation of the CDM investment intensity. Our econometric model controls for households' unobserved heterogeneity (fixed effects), lagged temporal effects, and the spatial indirect effects of CDM investments. That is, we consider that CDM investments could also affect neighbouring regions other than those receiving the CDM investments. Finally, we also control for the potential heterogeneous effects of Hydro projects with respect to Non-Hydro ones. Our main findings suggest that CDM investments have not contributed to poverty alleviation; however, CDM Hydro investments have had a slight effect on households' per capita consumption expenditure.

This paper is structured as follows: After this introduction, Section 2 presents the literature review. Section 3 provides background information on CDM investments in Peru and descriptive statistics of our data. Section 4 describes the methodology. Section 5 presents and discusses our results. Section 6 concludes and provides brief policy implications.

2. CDM projects' contribution to sustainable development criteria

The primary objective of the CDM is to contribute to the SD of host countries, as laid out in *Article 12* of the Kyoto Protocol. Since the creation of this mechanism, the evaluation of CDM impacts in terms of development has been studied extensively in the literature. See Olsen (2007) and Spalding-Fecher et al. (2012) for a literature review.

Most studies have been based on qualitative evaluations using different criteria to analyse the contribution of CDM projects to the social, economic and environmental aspects of SD (Huq, 2002; Begg et al., 2003; Sutter, 2003; Anagnostopoulos et al., 2004; Sutter and Parreño, 2007; Olsen and Fenhann, 2008). The *United nations framework convention on climate change* (UNFCCC, 2012) suggested, for example, 10 indicators for evaluating the ex-ante (potential) effects of 3864 CDM projects on SD and concluded that the most impacted variables were "Job creation" and "Poverty alleviation". In their analysis of 744 CDM projects, Olsen and Fenhann (2008) demonstrated that the criteria "Job creation", "Economic growth", "Air quality", "Access to energy", and "Well-being" of the citizenry are the most commonly cited as "potentially beneficial". Watson and Fankhauser (2009) showed that "local employment generation" is the most important contribution of such mechanisms and that renewable energy CDM's contribute more to SD than do other types of projects. The authors do not find evidence supporting the idea that small-scale CDM projects would have a larger impact on SD than would large-scale projects. Subbarao and Lloyd (2011) have studied 500 small-scale CDM projects using 10 indicators, and they show that rural renewable energy projects could have a positive potential impact on poverty. In a sample of 46 CDM Hydro projects developed in Brazil, Fernández et al. (2014) showed that such projects had an especially favourable effect on the "Job creation" variable. However, other studies argued that the impact of CDM's on development is of little significance (Sutter and Parreño, 2007). For instance, Sirohi (2007) studied 65 CDM projects in India and concluded that the CDM projects had no effect on poverty reduction. Similarly, Crowe (2013), in a sampling of 114 CDM projects, estimated that 74% of projects had no effect on poverty, 16% had a weak impact, and that only 10% of projects had either a strong or a moderate impact on poverty.

Nevertheless, these studies have two caveats. First, they are based on the ex-ante information provided by the Project Design Document (PDD) with a view toward its approval. Second, due to the projects' duration (medium- to long-term, i.e., 7 years to 21 years),[3] the potential effects are not verified or quantified ex-post. Indeed, the information pertaining to development goals listed in the PDDs is often incomplete and is subject to discussion at both quantitative and qualitative levels.

To evaluate the effects of the CDM in the host country, certain authors have given priority to quantitative ex-ante analysis that is primarily focused on assessing the CDM's potential to reduce greenhouse gas emissions (Mathy et al., 2001; Kallbekken, 2007; Zhang and Wang, 2011; Huang and Barker, 2012; Böhringer et al., 2015). Other authors have centred their analysis on the contribution of the CDM in terms of

[3] A maximum of seven years, with a possibility of being renewed twice.

technology transfer (Dechezleprêtre et al., 2008, 2009). Some researchers have also adopted diverse quantitative approaches to evaluate the contribution of CDMs to SD. He et al. (2014) estimated the ex-post impacts of CDM projects in 58 countries between 2005 and 2010. From a "Dynamic Panel Model", the authors showed that the CDM projects had a significant impact on SD in the host countries. Based on an Input-Output approach, Wang et al. (2013) assessed the impacts of the CDM on Chinese employment. They concluded that, even if certain projects have destroyed direct jobs, investments in CDM projects have resulted in the creation of numerous indirect jobs, with a notably unfavourable contribution of CDM Hydro projects. However, outside the scope of CDM investments, Zhang et al. (2017), using a difference-in-difference estimation approach, found that Hydro projects have had a statistically significant impact on Chinese households' revenue.

With the goal of contributing to this literature, our study follows a quantitative ex-post approach that accounts for CDMs' regional indirect effects on neighbouring regions by means of spatial econometric specification. We also consider the heterogeneous effects that result from two different types of CDM investments: Hydro and Non-Hydro projects.

The role of monetary welfare indicators

Although household consumption expenditure and the poverty rate are incomplete variables to measure households' well-being, the literature on development economics recognizes that both variables allow a good initial approximation of the level of household welfare, given that it measures the capacity of satisfying a set of food and non-food goods and services (Moratti and Natali, 2012). Moreover, data availability makes these two variables attractive for empirical analysis. In fact, many studies assess the impact of economic policies on household welfare using consumption expenditure and the poverty rate as proxy indicators of household welfare that are available in most household surveys (Biyase and Zwane, 2018; Hancevic et al., 2016). Finally, consumption expenditure and poverty have been selected as household welfare variables since in most project design documents (PDDs), poverty alleviation or job creation were mentioned as potential benefits of CDM projects. On the contrary, the potential impacts of CDM projects on education, health or nutrition are rarely cited.

3. Clean development mechanism and welfare in Peru

3.1. An overview

On a global scale, out of 7770 registered CDM projects in May 2017, 71% consisted of renewable energy projects. Of that number, 31% were classified as wind power type projects, 26% as hydro, 9% as biomass, and 5.2% as solar. Peru has 61 Registered CDM projects, 80% of which are renewable energy projects, with the hydro type making up 60% of that number. Peru ranks fifth in the world in the development of hydro projects, just behind major developing countries, such as Brazil, China, and India (Fenhann, 2017).

Peru, through intermediary organisations, such as *The National Environmental Fund* (FONAM) and *the Ministry of Environment* (MINAM), responsible for climate change policies,[4] is particularly active in the CDM market (Pécastaing, 2013) – total investments amount to $4.9 billion (Fenhann, 2017), including $3.6 billion for hydro projects alone (i.e., 73.4% of total investments in CDM projects). Most Peruvian CDM projects are located in the Lima region (16 projects), followed by Ancash (8), Piura (6) and Huánuco (4).

However, in terms of investment, Huánuco CDM's received the largest amount, at $1.2 billion (24.5% of total investment); followed by Lima, at $0.9 billion (19.1% of total investments); and Huancavelica with $842 million (17.1% of total investments). With the exception of Lima, these regions have some of the highest poverty rates in Peru: 34.5% for Huánuco and 43.7% for Huancavelica, compared to the national average of 24.4% (INEI-National Institute of Statistics and Information, 2017).

3.1.1. Databases

To analyse the relationship between CDM investments and household well-being in Peru, we exploited different databases and sources.

For CDM projects, we used the CDM pipeline 2017[5] (Fenhann, 2017), which contains general information about each CDM[6] project (type, location, amount invested, and technology used). We have also analysed every PDD to obtain more precise information on the potential beneficial effects of a given project on SD, in addition to obtaining certain information through Peruvian institutions, such as either FONAM – Fondo Nacional del Ambiente/National Environmental Fund (2011) or MINAM, that oversee CDM's.

Regarding our well-being indicators (household consumption expenditure and poverty status), our study draws on a household panel survey on living conditions in Peru (ENAHO) published by the National Institute of Statistics (INEI-National Institute of Statistics and Information, 2017). This nationally representative survey contains a set of socioeconomic indicators that describe both household and individual characteristics in Peru. The ENAHO provides information on trends in household consumption expenditures – generally viewed in the literature as a reliable monetary indicator of well-being (Townsend, 1954; Richardson and Atkinson, 1970; Thompson, 2013) – during 2011–2015.

3.1.2. Matching the CDM pipeline and ENAHO panel survey

The CDM pipeline main database (Fenhann, 2017) registers 61 CDM projects distributed across 47 Peruvian provinces from 2005 to 2015. However, only 46 projects, affecting 37 provinces, report investments of approximately $3.9 billion (see Fig. 2.) during our period of analysis (2011–2015). On the other hand, our nationally representative household survey (ENAHO) samples more than 120 provinces, 30 of which are affected by 32 CDM investment projects. Thus, 7 affected provinces went missing in our matched database due to the sampling design of the ENAHO survey. Consequently, our analysis assesses the impact of 32 projects across 30 provinces, with an investment of approximately $3.4 billion.

Once the CDM investment amount is matched at the province level with the ENAHO survey, we calculate an investment intensity indicator as the CDM investment amount per capita at the province level. Our final database then consists of a longitudinal sample of 2239 Peruvian households between 2011 and 2015.

3.2. Descriptive statistics

Between 2011 and 2015, total CDM investments rose to $3.4 billion, with a surge of investment (65% of the total) in 2012 and 2013, 2012 being the deadline to register CDM projects during the first enforcement period of the Kyoto Protocol.

Regarding the geographical distribution of investment flows, the Sierra region of Peru has received the greater share of investment (approximately $2.1 billion); the next highest is the Costa region, which has received $1.2 billion, $156 million of which has gone to Lima. In fact, Hydro type projects have been developed principally in the Sierra region, with an investment of approximately $2 billion, compared to the $230 million received by the Costa region. Most of the investments

[4] MINAM evaluates project quality. FONAM's role is to promote CDM's. The estimated potential investment by FONAM is approximately $13 billion.

[5] Database updated in May 2017.

[6] For more details on the various projects, we also consulted the PDDs published on the UNFCCC website.

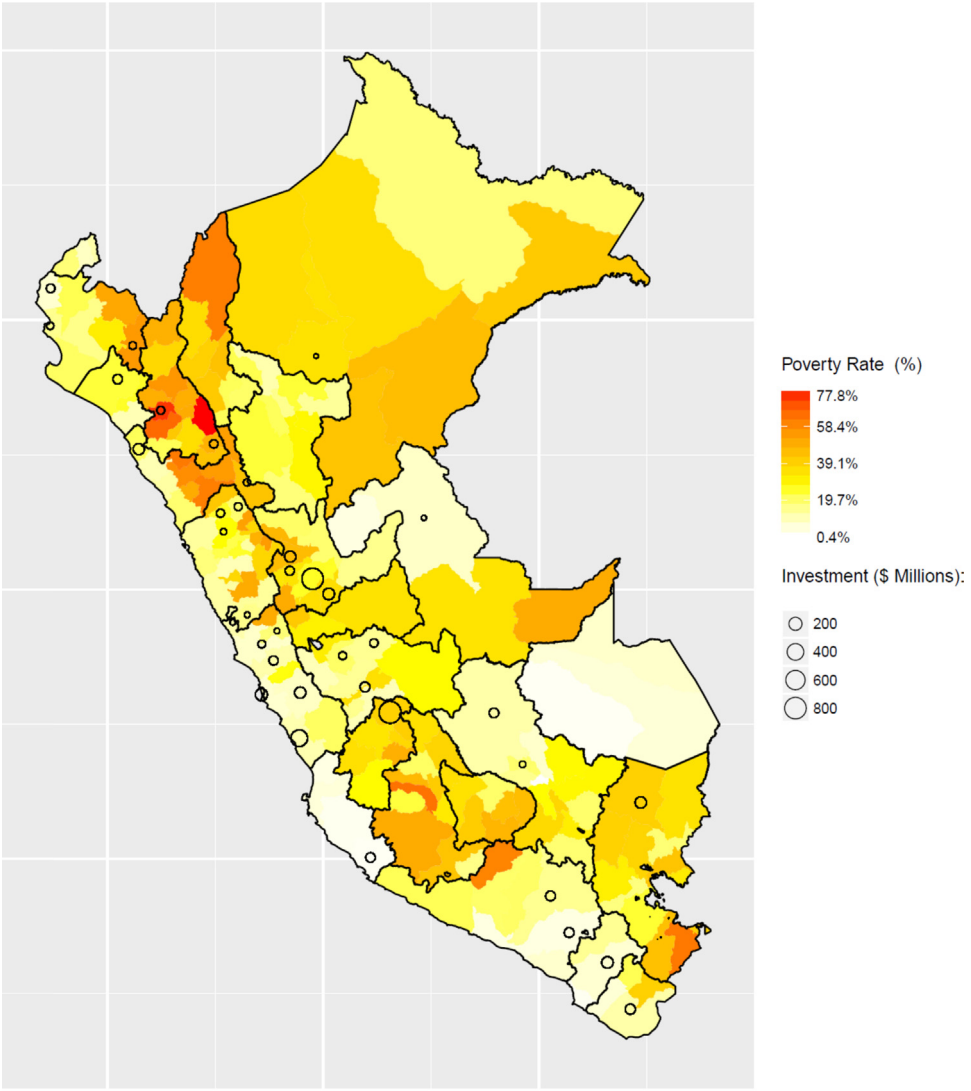

Fig. 2. CDM investment and poverty.
Source: Based on ENAHO surveys and Fenhann (2017).

– and a large part of the Hydro type investments – are concentrated in Peruvian regions that have especially high poverty levels; these include the *Sierra Central* (Huancavelica 38%, Huánuco 32%) and the *Sierra Norte* (Cajamarca). We notice that the regions of Lima and Callao exhibit relatively low poverty rates (around 10%), and both receive approximately $780 million of CDM investments.

Table 1 highlights the comparative evolution of Hydro vs. Non-Hydro projects for 2011–2015. On average, Hydro CDM investments accounted for approximately 68% of the total CDM investments. During this period, the share of Hydro investments increased, eventually reaching 100% in 2015. We notice that the poverty rate tends to be higher in provinces receiving Hydro investments. Average household consumption expenditures were slightly higher ($1918) than the average expenditures of households in provinces that were the recipients of CDM investments ($1829). More specifically, the average expenditures of households in regions that received Hydro type CDM investments is significantly lower ($1450) than are the average expenditures of households that received Non-Hydro investments ($2304).

Additionally, Peruvian households that have received CDM investments have a poverty rate (26.2%) that is slightly higher than the national average, with poverty affecting 23.6% of the population. On average, households received a direct investment of $477, as opposed to $381 of indirect investment. By category, that disaggregates to $578 in direct investments for Hydro projects and $326 of Non-Hydro investments, while indirect investments come to $325.7 and $55.5, respectively. In terms of the allocation of CDM investments received by households,[7] direct investments received per head (Total or Hydro type) have been more important in the poorest households, while, on the other hand, received indirect investment in Hydro is higher in better-off households.

4. Methodology

To estimate the impact of Peru's CDM projects on SD measured by households' welfare, we apply a quasi-experimental approach that allows for a proper identification of a causal relationship in the absence of data generated by an experimental design (Gertler et al., 2011; Khandker et al., 2010; Meyer, 1995). Our outcomes of interest are a monetary measure of welfare – household consumption expenditure – its corresponding monetary poverty indicator and employment at the household level.

The identification of a causal relationship relies on the random

[7] Households are classed according to average expenditures per household.

Table 1
Descriptive statistics.
Source: Authors calculation from ENAHO surveys and CDM Pipeline (Fenhann, 2017).

	2011	2012	2013	2014	2015	Average
Direct investment (millions of USD)						
Total	233.1	1188.7	1034.9	602.0	351.5	*3410.2*
Hydro (in %)	32	52	77	81	100	*68*
Non-Hydro (in %)	68	48	23	19	–	*32*
Households' consumption expenditure (mean in USD per year)[a]						
Total	1675.1	1804.0	1955.7	1996.9	2161.8	*1918.7*
By provinces receiving:						
Investment	2308.3	1958.6	1426.4	1515.5	1705.8	*1828.8*
Hydro investment	2172.0	1246.0	1413.4	1333.8	1705.8	*1450.2*
Non-Hydro investment	2365.3	2351.1	1847.1	2168.2	–	*2304.8*
Poverty rate (mean in %) Total	27.1%	25.7%	22.0%	23.0%	20.3%	*23.6%*
By provinces receiving:						
Investment	8.6%	21.2%	36.4%	41.6%	40.7%	*26.2%*
Hydro investment	7.3%	41.6%	39.2%	51.9%	40.7%	*39.4%*
Non-Hydro investment	9.2%	9.1%	9.1%	4.6%	–	*8.9%*
Employment (mean household's members with employment)						
Total	2.18	2.16	2.13	2.07	1.98	*2.10*
By provinces receiving:						
Investment	2.20	2.11	2.13	1.96	1.97	*2.10*
Hydro investment	1.95	2.23	2.19	1.96	1.97	*2.12*
Non-Hydro investment	2.31	2.05	1.91	1.95	–	*2.09*
Direct investment by Households (Mean in USD)						
Total	100.3	523.8	557.1	606.3	570.4	*477.4*
Hydro	125.9	648.1	562.1	727	570.4	*577.9*
Non-Hydro	89.6	430.3	294.1	172.7	–	*326.6*
Indirect investment by Households (Mean in USD)						
Total	201.6	832.2	521.5	221.8	129	*381.2*
Hydro	186.4	653.6	462.7	196.7	129	*325.7*
Non-Hydro	15.2	178.6	58.8	25.1	–	*55.5*

[a] The exchange rate used was 3.2 soles per $1.

assignment of a treatment (CDM investment) into a subpopulation of treated units, in our case, regions affected by the CDM projects. Thus, we first need to argue how the CDM investment assignment can be considered exogenous to our welfare indicators. It should be noticed that, a priori, one may argue that CDM projects risk being allocated to developed (less poor) regions, which would imply that the treatment is partly caused by the outcome. This would lead to a reverse causality bias of our impact estimation.

We distinguish between Hydro and Non-Hydro investments, as their allocation decisions may be driven by different mechanisms. As can be seen (Fig. 3), households' consumption expenditure across CDM-affected and unaffected regions is evenly distributed for our period of analysis (2011–2015). This suggests that the CDM investment (our treatment) is randomly assigned across regions, i.e., irrespective of households' welfare conditions.

4.1. Econometric specification

Since the CDM investment distribution is registered at the province level (I_j), we formally define the per-capita CDM investment at the *j-th* province level with respect to its population size (N_j), that is: $x_j = I_j/N_j$. In this way we control for the greater effect that an equal investment amount is expected to have on a smaller province. The main outcome of interest, the *i-th* household's per-capita consumption expenditure at the *j-th* region, is denoted y_{j_i}. Given that a CDM investment effect might not be bounded to a province political delimitation, we must also account for the potential indirect effects of neighbouring provinces' CDM investments.

This prompts a panel spatial econometric specification analogous to the one proposed by Benson et al. (2005) to study the local prevalence of poverty in Malawi. Formally and in matrix notation, our model can be written as generalized difference-in-difference (GDiD) as in Autor (2003) and Hoynes et al. (2015) among others:

$$log\boldsymbol{y_t} = \boldsymbol{x_{jt}}\gamma_1 + \widetilde{\boldsymbol{x}}_{\boldsymbol{jt}}\gamma_2 + \boldsymbol{Z_t}\boldsymbol{\beta} + \boldsymbol{\mu} + \boldsymbol{\mu_t} + \boldsymbol{u_t} \quad (1)$$

$$\widetilde{\mathbf{x}}_{\mathbf{jt}} = \boldsymbol{W}\boldsymbol{x_{jt}}$$

where $\boldsymbol{y_t}$ is a vector of household level observations on the outcome of interest at time *t* and $\boldsymbol{x_{jt}}$ is a vector of per-capita CDM investments at the province level (and time t) that exhibits repeated values for households within the same province. Thus, the γ_1 parameter represents the direct relative effect of a CDM investment on households' welfare indicators. The effects of non-local CDM investments are captured by $\widetilde{\mathbf{x}}_{\mathbf{jt}}$, a vector of weighted per-capita investments in neighbouring provinces, where $\boldsymbol{W}$ is a symmetric spatial weights matrix whose elements are inversely proportional to the geographical distance between provinces (Anselin et al., 2008). Thus, γ_2 measures the indirect effect on a household (in province *j*) that results from the CDM investments in the surrounding provinces (other than *j*). The many control variables that affect our outcome are included in $\boldsymbol{Z_t}$ (Appendix B), a matrix with as many columns as controls. Time invariant household unobserved characteristics are represented by the $\boldsymbol{\mu}$ vector, whereas $\boldsymbol{\mu_t}$ represents year specific unobserved random components. Finally, $\boldsymbol{u_t}$ stands for the idiosyncratic error term at the household level. It should be noticed that the group (province) specific effects included in every GDiD specification are override by the household effects ($\boldsymbol{\mu}$) as they are nested into provinces.

The literature suggests a wide range of possibilities for the specification of the spatial weights matrix (Kelejian and Prucha, 2010; Lesage, 1998). In our case, we define the *i-h* provinces weight as being inversely proportional to the geographical distance between them (noted d_{ih}). Such weights are normalised by the maximum distance between provinces (d_m) (Kelejian and Prucha, 2010) :

$$[\boldsymbol{W}]_{\boldsymbol{ih}} = \begin{cases} \left[\frac{d_{ih}}{d_m}\right]^{-1}; i \neq h \\ 0; i = h \end{cases}$$

We avoid alternative normalisations[8] that do not preserve the symmetry of the weights matrix, since two provinces should share equal weights with respect to their CDM investments. The normalisation cancels out the distance measurement units, hence, $[\boldsymbol{W}]_{\boldsymbol{ih}}$ is dimensionless and $\widetilde{\mathbf{x}}_{\mathbf{jt}}$ can be interpreted as a weighted average of neighbouring investments whose weights do not add up to one but that keep the property of symmetry.

4.2. Augmented specifications

The channels linking CDM investments throughout the regional economies may exhibit lagged effects, which could be captured by adding lagged $\boldsymbol{x_{jt}}$ and $\widetilde{\mathbf{x}}_{\mathbf{jt}}$ terms to the previous specification. One may argue that CDM investment affects labor productivity through the increase in the capital stock and technology transfer. This is expected to rise labor demand and wages. Depending on labor market rigidities, this effect can be contemporaneous or might be identified after a one-year period lag.

Furthermore, each CDM investment type may exhibit a particular effect on households' welfare; thus we distinguish between Hydro ($\boldsymbol{x_{jt}^h}$) and Non-Hydro ($\boldsymbol{x_{jt}^n}$) per capita investments:

$$log\boldsymbol{y_t} = \boldsymbol{x_{jt}^h}\gamma_1^h + \boldsymbol{x_{jt}^n}\gamma_1^n + \boldsymbol{x_{jt-1}^h}\theta_1^h + \boldsymbol{x_{jt-1}^n}\theta_1^n + \widetilde{\boldsymbol{x}}_{\boldsymbol{jt}}^{\boldsymbol{h}}\gamma_2 + \widetilde{\boldsymbol{x}}_{\boldsymbol{jt}}^{\boldsymbol{n}}\gamma_2 + \widetilde{\boldsymbol{x}}_{\boldsymbol{jt-1}}^{\boldsymbol{h}}\theta_2 + \widetilde{\boldsymbol{x}}_{\boldsymbol{jt-1}}^{\boldsymbol{n}}\theta_2 + \boldsymbol{Z_t}\boldsymbol{\beta} + \boldsymbol{\mu} + \boldsymbol{\mu_t} + \boldsymbol{u_t} \quad (2)$$

The effects of CDM investments on poverty alleviation are estimated

[8] Row-normalisations deliver weights that add up to 1, making each (row) element of $\widetilde{\mathbf{x}}_{\mathbf{jt}}$ have a straightforward interpretation as a weighted average of neighbouring investments (Cliff and Ord, 1969). Nevertheless, such normalisations imply asymmetric weights ($\mathbf{w}_{ij} \neq \mathbf{w}_{ji}$), despite the obvious symmetric distance between provinces *j* and *i*.

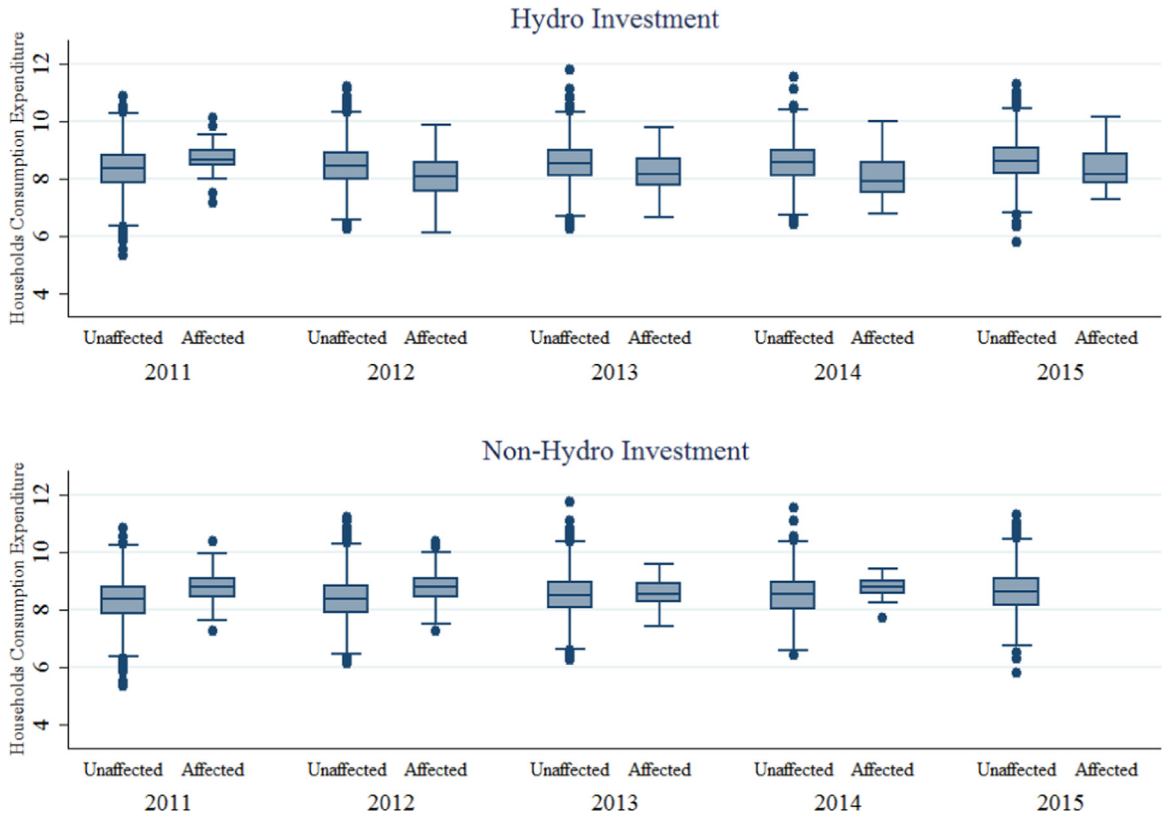

Fig. 3. Households consumption expenditure distribution (Log), by CDM affected and unaffected provinces.
Source: Authors elaboration from ENAHO surveys (2011–2015) and CDM investments' database.

Table 2
Average treatment effects of CDM investments on welfare: households consumption expenditure and poverty.

	Household consumption expenditure (log)				Poverty rate	Employment	Employment ratio[a]
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Direct effects (x_{jt})							
Investment	0.02**	0.01*					
	(0.01)	(0.01)					
Investment (t − 1)		0.00					
		(0.01)					
Hydro Investment			0.02**	0.02*	− 0.07	0.00	0.00
			(0.01)	(0.01)	(0.11)	(0.02)	(0.00)
Non-Hydro Investment			0.01	0.01	-0.15	0.02	0.01
			(0.02)	(0.02)	(0.26)	(0.02)	(0.01)
Hydro Investment (t − 1)				0.01	0.13	− 0.01	0.00
				(0.01)	(0.11)	(0.02)	(0.01)
Non-Hydro Investment (t − 1)				− 0.01	0.10	0.02	0.00
				(0.01)	(0.15)	(0.02)	(0.01)
Indirect (spatial) effects ($\tilde{x}_{jt}$)							
Investment	− 0.01	− 0,01					
	(0.01)	(0.01)					
Investment (t − 1)		− 0,00					
		(0.01)					
Hydro Investment			0.00	0.00	0.01	− 0.01	− 0.01*
			(0.01)	(0.01)	(0.23)	(0.02)	(0.00)
Non-Hydro Investment			0.00	0.00	0.1	− 0.01**	0.00
			(0.00)	(0.00)	(0.08)	(0.00)	(0.00)
Hydro Investment (t − 1)			− 0.01*	0.01	0.00	0.00	
				(0.01)	(0.07)	(0.01)	(0.00)
Non-Hydro Investment (t − 1)				0.01*	0.02	− 0.01	0.00
				(0.00)	(0.06)	(0.01)	(0.00)
R-squared	0,10	0,11	0,11	0,10	0.05		

Notes: Robust standard errors in parentheses (clustered at the province and household level).
[a] This is the ratio of employed household members to the household's labor force size.
* $p < 0.1$.
** $p < 0.05$.

by a probit model conditioned on the same regressors as in Eq. (2). The potential bias that would arise from the potential correlation between households' unobserved (μ) and observed characteristics (Z_t, x_{jt}) is treated by implementing a fixed-effect probit estimation (Chamberlain, 1980; Hamerle and Ronning, 1995). Since the direct and indirect effects are identified by variations of CDM investments at the province level, while our observation units are the households, we correct for the clustering effect on parameters' standard deviation by employing clustered standard errors, both at the province and household level (Wooldridge, 2003). The household-level clustering is a consequence of the implied autocorrelation of households within our panel (2011–2015).

Regarding the observed characteristics (Z_t), we identify three types of controls according to the literature: i) household head characteristics (gender, age, civil status, and educational attainment, among others); ii) household members' characteristics (the dependency ratio, the number of female members, the share of household members with social security coverage, and home ownership status) and; iii) regional economic characteristics (department-region, GDP, and household density) (Anyanwu, 2014; Benson et al., 2005; Chattopadhyay et al., 2013; Nicita, 2009).

5. Results and discussion

The estimated impact of the CDM investment is presented as an average effect. For instance, consider Eq. (1) and its corresponding column (1) in Table 2. As a first element, we report the average direct effect of the CDM investment: $\gamma_1\bar{x}$, where γ_1 is estimated by the econometric model, whereas $\bar{x}$ is the historical mean of the CDM per-capita investment (x_{jt}) across provinces affected by CDM investments. Thus, the resulting magnitude (0.01*) is interpreted as a 1% average increase in households' per-capita consumption that results from the CDM investment.

In the first specification (column 1), we identify a statistically significant but slight 2% direct effect and no indirect spatial effects. Lagged effects (column 2), both direct and indirect (spatial), are statistically non-significant suggesting that CDM effects are only direct and contemporaneous. A third specification (column 3) that controls for the heterogeneous channels of Hydro and Non-Hydro investments, suggests that Hydro projects are more effective (2%) in enhancing households' welfare while verifying the lack of significance of indirect effects. Similarly, controlling for heterogeneous (Hydro and Non-Hydro) lagged investment effects (column 4) verifies the lack of statistically significant indirect and lagged effects. Furthermore, our results point to a lack of statistically significant CDM effects on poverty alleviation (column 5), despite the slight but significant effect on consumption expenditure. Similar to our results on poverty alleviation, the last specifications (column 6 and column 7) show a robust lack of statistically significant effects (at a 5% level) on employment for both outcomes, employed household members and the employment ratio at the household members.

The non-statistically significant indirect (spatial) effects could be explained by the lack of infrastructure and economic integration of Peru's regional markets in the regions affected by the CDM investments (Calderón and Servén, 2004). The lack of direct impacts, even after one period, provide evidence on the transmission channel rigidities linking CDM investments to welfare. That is, the higher labor productivity that results from CDM investment, might not translate into higher employment, labor income and poverty reduction due to structural factors. Since most of the CDM investments aim projects that are capital-intensive (e.g. Hydro projects, see Table A1) the labor market channel is likely to be playing a minor role. Pegg (2006) identifies analog effects in the case of mining investments – a capital intensive sector – where non clear poverty reduction effects were identified across countries. Among the many factors explaining this effect, Pegg (2006) provides evidence of the limited direct effects of mining projects due to the low labor share participation in total value added.

Even though the PDDs of most CDM projects emphasize that the main objective of the project is to contribute to SD, most do not provide either quantitative goals or a description of the means to achieve such goals. For instance, only six projects (19%) detailed their objectives regarding job creation and educational benefits (Table A1, Appendix A).

The statistical significance of the CDM Hydro investments (on consumption expenditure) with respect to Non-Hydro investment can be attributed to the Hydro PDDs, which exhibit more accurate social objectives (see the "*Platanal Hydropower plant*" PDD) than do Non-Hydro PDDs (see the "*Cupisnique Wind Farm*" PDD). Among the main potential benefits of Hydro projects, the corresponding PDDs mention benefits related to households' income generation: "Job creation" (22% of Hydro project PDDs),[9] "Support to local economy" [10] (26% of Hydro project PDDs) or/and "Better electricity supply" (17% of Hydro project PDDs).[11] On the contrary, just one *Non-Hydro* CDM project detailed its potential effect on social concern.

6. Conclusions and policy implications

Clean Development Mechanism (CDM) investments, by their very nature, are intended to enhance technology transfers towards emerging economies while contributing to their sustainable development (SD). This paper studies CDM investment effects on SD through key monetary welfare indicators (consumption expenditure and poverty). The microeconometric analysis builds on a panel of Peruvian households (from 2011 to 2015) and exploits exogenous variations of CDM Hydro and Non-Hydro investments through affected and unaffected provinces while considering indirect (spatial) and lagged effects. Our results suggest that Peru's CDM investments have been heterogeneous and that only Hydro investments have led to a slight 2% welfare (consumption expenditure) increase in affected provinces. We also find that CDM investments have had no effect on employment and poverty alleviation. These findings are in line with the literature that identifies analogous effects with alternative SD measures and levels of aggregation (Dirix et al., 2016; Sirohi, 2007; Subbarao and Lloyd, 2011; Sutter and Parreño, 2007; Wang et al., 2013). The literature also identifies two main factors that may explain Peru's weak CDM effects on welfare: The lack of sharp definitions of SD (Du Monceau, Brohe, 2011; Fuhr and Lederer, 2009; Newell and Bumpus, 2012) and host countries' eagerness for technology transfer, which in turn, eases low social minimum requirements for candidate CDM projects (Crowe, 2013; Drupp, 2011). Our analysis of 33 PDD's corresponding to Peruvian CDM projects not only verifies the lack of common developmental objectives – only six projects provide some estimates for job creation rates – but also confirms the absence of institutional commitments devoted to evaluating their effectiveness. Thus, our findings suggest the need to strengthen the institutional framework of CDM by identifying key development definitions and indicators.

In the context of international climate change negotiations, the SD requirements of the "Future Reformed CDM" should be better monitored, assessed and supported to improve the household welfare and more generally, to contribute to SD in developing countries. This could be achieved by enforcing the compliance with the PDDs SD goals and by prioritizing investment projects that are expected to deliver higher ex-

[9] For example, the CDM project *"Huasahuasi I and II Hydroelectric Power Plant"* stated that it will generate 146 new Jobs.

[10] For example, the CDM project "*Platanal Hydropower plant*", representing an investment of $485 million, planned to invest $225 million in the economy and $15 million in Jobs.

[11] *"Taurichuco Hydropower Project", "Santa Cruz I Hydroelectric Power Plant"* and *"Purmacana Hydroelectric Power Plant"* are some of the projects that seek to secure an electricity supply in local communities.

post effects. Similarly, regions exhibiting the highest vulnerability in terms of SD indicators could be prioritized. In Peru's case particularly, our research suggests that Hydro projects could be given a higher priority in regions exhibiting the highest poverty rates, provided that compliance with SD goals is enforced. Furthermore, our methodology could be used to evaluate CDM impacts on household´ welfare in others middle-income countries since most of them are very attractive for climate finance mechanisms and face important welfare challenges.

Acknowledgements

The authors thank Omar Alburqueque-Chávez for the excellent research assistance.

Appendix A

See Table A1.

Table A1
Sample – CDM projects.

ID	Title
CDM10508	Chaglla Hydroelectric Power Plant CDM Project
CDM10991	Cerro del Aguila Hydroelectric Project
CDM03195	El Platanal Hydropower Plant
CDM03440	Ventanilla Conversion from Single-cycle to Combined-cycle Power Generation Project
CDM09128	Marañon Hydroelectric Project
CDM07973	PANAMERICANA SOLAR 20 TS: 20 MW Solar Photovoltaic Power Plant
CDM01301	Rehabilitation of the Callahuanca hydroelectric power station
CDM09338	Angel I, Angel II and Angel III Hydroelectric Power Plants
CDM10655	Cupisnique Wind Farm Project
CDM10703	Olmos 1 Hydroelectric Power Plant
CDM07972	TACNA SOLAR 20 TS: 20 MW Solar Photovoltaic Power Plant
CDM03014	Cheves Hydro Power Project, Peru
CDM09419	Runatullo III Hydroelectric Power Plant
CDM10439	Santa Teresa Hydropower Plant
CDM12077	MAJES SOLAR 20T: 20 MW Solar Photovoltaic Power Plant
CDM02855	La Joya Hydroelectric Plant
CDM08955	Marcona Wind Farm
CDM06637	Baños V Hydroelectric Power Plant (BVHPPP)
CDM10665	Talara Wind Farm Project
CDM01393	La Virgen Hydroelectric Plant
CDM11367	Potrero Hydropower Plant, Peru
CDM07593	Manta Hydroelectric Power Plant
CDM08332	Las Pizarras Project
CDM11820	Taurichuco Hydropower Project
CDM06270	Huasahuasi I and II Hydroelectric Power Plant
CDM05697	Maple Bagasse Cogeneration Plant
CDM02799	Santa Cruz I Hydroelectric Power Plant
CDM06150	Pias I Hydroelectric Power Plant
CDM04606	Yanapampa Hydroelectric Power Plant
CDM06271	Purmacana Hydroelectric Power Plant
CDM04044	Triplay Amazonico Methane Avoidance Project
CDM07572	Methane recovery in wastewater treatment system at Yurimaguas industrial plant, Peru.

Notes: Based on CDM Pipeline (Fenhann, 2017).

Appendix B

See Table B1.

Table B1
Estimation results.

	Household consumption expenditure (log)				Poverty rate	Employment	Employment ratio[a]
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Household head							
Sex of head of Household (1 = Woman, 0 = Man)	− 0.04	− 0.04	− 0.04	− 0.04	0.65	− 0.07*	− 0.02
	(0.034)	(0.034)	(0.034)	(0.034)	(0.557)	(0.034)	(0.012)
Age of Head of Household	− 0.01***	− 0.01***	− 0.01***	− 0.01***	0.06	0.03***	− 0.00
	(0.004)	(0.004)	(0.004)	(0.004)	(0.041)	(0.006)	(0.002)
Age of Head of Householdˆ2	0.00**	0.00**	0.00**	0.00**	0.00	− 0.00***	0.00**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

(*continued on next page*)

Table B1 (*continued*)

	Household consumption expenditure (log)				Poverty rate	Employment	Employment ratio[a]
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Marital status of Head of Household (1 = Married, 0 = other)	− 0.22***	− 0.22***	− 0.22***	− 0.22***	0.86***	0.30***	− 0.00
	(0.019)	(0.019)	(0.019)	(0.019)	(0.292)	(0.037)	(0.029)
Native Language of Head of Household (1 = Spanish, 0 = Other)	0.00	0.00	0.00	0.00	− 0.28*	− 0.02	− 0.01
	(0.017)	(0.017)	(0.017)	(0.017)	(0.1599	(0.029)	(0.021)
Head Household have Middle education (1 = Have this Level, 0 = other)	0.04***	0.04***	0.04***	0.04***	− 0.43	− 0.01	0.01*
	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)	(0.035)	(0.006)
Head Household have Higher education (1 = Have this Level, 0 = other)	0.11***	0.11***	0.11***	0.11***	− 1.47***	− 0.03	0.00
	(0.019)	(0.019)	(0.019)	(0.019)	(0.503)	(0.054)	(0.008)
The head household works in agriculture sector	− 0.09***	− 0.09***	− 0.09***	− 0.09***	0.79**		
	(0.027)	(0.027)	(0.027)	(0.027)	(0.326)		
The head household works in manufacture sector	0.00	0.00	0.00	0.00	0.00		
	(0.04)	− 0.039	(0.04)	(0.039)	-(0.40)		
The head household works in business sector	− 0.03	− 0.03	− 0.03	− 0.03	− 0.24		
	(0.021)	(0.021)	(0.021)	(0.021)	(0.347)		
The head household works in transport sector	− 0.02	− 0.02	− 0.02	− 0.02	0.66*		
	(0.035)	(0.035)	(0.035)	(0.035)	(0.393)		
The head household works in mining sector	− 0.11***	− 0.11***	− 0.11***	− 0.11***	1.59		
	(0.041)	(0.04)	(0.041)	(0.04)	(1.246)		
The head household works in services sector	− 0.04	− 0.04	− 0.04	− 0.04	0.29		
	(0.027)	(0.026)	(0.027)	(0.026)	(0.374)		
The head household works in energy sector	− 0.07**	− 0.07**	− 0.07**	− 0.07**	− 0.21		
	(0.036)	(0.036)	(0.036)	(0.035)	(0.463)		
Household							
The home have a property tittle	0.02*	0.02*	0.02*	0.02*	− 0.03	0.02	− 0.00
	(0.01)	(0.01)	(0.01)	(0.01)	(0.253)	(0.017)	(0.012)
The home has access to electricity	0.11***	0.10***	0.11***	0.10***	− 0.42	− 0.01	0.01
	(0.028)	(0.028)	(0.028)	(0.028)	(0.271)	(0.024)	(0.009)
The household use PLG/natural gas/electricity to cook	0.07***	0.07***	0.07***	0.07***	− 0.22	0.04**	− 0.00
	(0.014)	(0.014)	(0.014)	(0.014)	(0.136)	(0.018)	(0.005)
Characteristics of the Households							
Persons under 15 years old and over 65 years old (% of the members of household)	− 0.23***	− 0.23***	− 0.23***	− 0.23***	1.07***	− 0.36***	− 0.01
	(0.028)	(0.028)	(0.028)	(0.028)	(0.284)	(0.075)	(0.009)
Woman (% of the members of household)	− 0.08	− 0.08	− 0.08	− 0.08	− 0.61	− 0.11	− 0.01
	(0.056)	(0.056)	(0.056)	(0.056)	(0.56)	(0.096)	(0.017)
Persons with health insurance (% of the members of household)	0.04***	0.04***	0.04***	0.04***	− 0.06	0.04**	0.03***
	(0.012)	(0.012)	(0.012)	(0.012)	(0.264)	(0.021)	(0.007)
Household members with job (% of the members of household)	0.24***	0.24***	0.24***	0.24***	− 1.49***		
	(0.024)	(0.024)	(0.024)	(0.024)	(0.286)		
Province level							
GPD Departamental	0.21	0.12	0.21	0.17	− 2.27	− 0.38**	− 0.07
	(0.13)	(0.14)	(0.131)	(0.145)	(1.632)	(0.150)	(0.051)
GPD Departamental (t − 1)		0.24		0.19	− 3.1	0.31**	0.02
		(0.171)		(0.174)	(2.01)	(0.133)	(0.062)
Indirect GPD Departamental	0.09**	0.07	0.09**	− 0.01	0.28	0.16**	0.01
	(0.044)	(0.075)	(0.045)	(0.1)	(0.992)	(0.076)	(0.031)
Indirect GPD Departamental (t − 1)		0.02		0.11	− 0.4	− 0.13	− 0.05
		(0.075)		(0.101)	(1.009)	(0.081)	(0.036)
Households by km^2	− 0.02	− 0.02	− 0.02	− 0.03	0.35	− 0.02	0.01
	(0.019)	(0.021)	(0.02)	(0.021)	(0.661)	(0.059)	(0.013)
Time effects							
2012.year	0.02	0.02	0.03	0.03	− 0.06	0.01	0.05***
	(0.027)	(0.026)	(0.032)	(0.036)	(0.47)	(0.038)	(0.016)
2013.year	0.07**	0.06*	0.07**	0.04	− 0.04	0.00	0.07***
	(0.032)	(0.031)	(0.033)	(0.037)	(0.475)	(0.038)	(0.017)
2014.year	0.07**	0.05	0.08**	0.02	0.49	− 0.04	0.07***
	(0.037)	(0.043)	(0.038)	(0.047)	(0.513)	(0.045)	(0.020)
2015.year	0.11**	0.08*	0.11**	0.07	0.49	− 0.11**	0.07***
	(0.043)	(0.046)	(0.045)	(0.049)	(0.538)	(0.048)	(0.020)
Constant	6.85***	6.47***	6.89***	6.30***			
	(0.585)	(0.65)	(0.608)	(0.685)			
Observations	11,195	11,195	11,195	11,195	4060	11,060	10,779
R-squared	0.1	0.11	0.11	0.1	0.05		
Number of id	2239	2239	2239	2239	812	2212	2202

Notes: Robust standard errors in parentheses (clustered at the province level).

[a] This is the ratio of employed household members to the household's labor force size.

* $p < 0.1$.

** $p < 0.05$.

*** $p < 0.01$.

References

Anagnostopoulos, K., Flamos, A., Kagiannas, A.G., Psarras, J., 2004. The impact of clean development mechanism in achieving sustainable development. Int. J. Environ. Pollut. 21 (1), 1–23.

Anselin, L., Gallo, Le, J., Jayet, H., 2008. Spatial Panel Econometrics. Advanced Studies in Theoretical and Applied Econometrics 46. pp. 625–660. https://doi.org/10.1007/978-3-540-75892-1_19.

Anyanwu, J.C., 2014. Marital status, household size and poverty in Nigeria: evidence from the 2009/2010 survey data. Afr. Dev. Rev. 26 (1), 118–137. https://doi.org/10.1111/1467-8268.12069.

Autor, D.H., 2003. Outsourcing at will: the contribution of unjust dismissal doctrine to the growth of employment outsourcing. J. Labor Econ. 21 (1), 1–42.

Begg, K., Parkinson, S., Van der Horst, D., Wilkinson, R., Theuri, D., Gitonga, S., Ageby, S., 2003. Encouraging CDM Energy Projects to Aid Poverty Alleviation. Final Report of Project R8037 Under the DFID KAR Programme. Centre for Environmental Strategy, University of Surrey, Surrey.

Benson, T., Chamberlin, J., Rhinehart, I., 2005. An investigation of the spatial determinants of the local prevalence of poverty in rural Malawi. Food Policy 30 (5–6), 532–550. https://doi.org/10.1016/j.foodpol.2005.09.004.

Biyase, M., Zwane, T., 2018. An empirical analysis of the determinants of poverty and household welfare in South Africa. J. Dev. Areas 52 (1), 115–130.

Böhringer, C., Rutherford, T.F., Springmann, M., 2015. Clean-development investments: an incentive-compatible CGE modelling framework. Environ. Resour. Econ. 60 (4), 633–651.

Calderón, C., Servén, L., 2004. The Effects of Infrastructure Development on Growth and Income Distribution. Policy Research Working Paper No. 3400. World Bank, Washington, D.C.

Chamberlain, G., 1980. Analysis of covariance with qualitative data. Rev. Econ. Stud. 47 (1), 225. https://doi.org/10.2307/2297110.

Chattopadhyay, S., Majumder, A., Jaman, H., 2013. Decomposition of inter-regional poverty gap in India: a spatial approach. Empir. Econ. 46 (1), 65–99. https://doi.org/10.1007/s00181-013-0683-8.

Cliff, A., Ord, J.K., 1969. The problem of spatial autocorrelation. In: Scott, A.J. (Ed.), London Papers in Regional Science 1, Studies in Regional Science, pp. 22–25.

Crowe, T.L., 2013. The potential of the CDM to deliver pro-poor benefits. Clim. Policy 13 (1), 58–79. https://doi.org/10.1080/14693062.2012.709080.

Dechezleprêtre, A., Glachant, M., Ménière, Y., 2008. The clean development mechanism and the international diffusion of technologies: an empirical study. Energy Policy 36 (4), 1273–1283.

Dechezleprêtre, A., Glachant, M., Ménière, Y., 2009. Technology transfer by CDM projects: a comparison of Brazil, China, India and Mexico. Energy Policy 37 (2), 703–711.

Dirix, J., Peeters, W., Sterckx, S., 2016. Is the clean development mechanism delivering benefits to the poorest communities in the developing world? A critical evaluation and proposals for reform. Environ. Dev. Sustain. 18 (3), 839–855. https://doi.org/10.1007/s10668-015-9680-8.

Drupp, M.A., 2011. Does the gold standard label hold its promise in delivering higher sustainable development benefits? A multi-criteria comparison of CDM projects. Energy Policy 39 (3), 1213–1227. https://doi.org/10.1016/j.enpol.2010.11.049.

Du Monceau, T., Brohe, A., 2011. Sustainable development and social equity. Briefing paper. AEA, energy and climate change consultancy. Retrieved from ⟨http://ec.europa.eu/clima/policies/ets/linking/docs/sustainable_development_en.pdf⟩.

Fenhann, J., 2017. UNEP Risø CDM Pipeline May 2017. Available at: ⟨http://www.CD4CDM.org⟩.

Fernández, L., de la Sota, C., Andrade, J.C.S., Lumbreras, J., Mazorra, J., 2014. Social development benefits of hydroelectricity CDM projects in Brazil. Int. J. Sustain. Dev. World Ecol. 21 (3), 246–258.

FONAM – Fondo Nacional del Ambiente/National Environmental Fund, 2011. Carbon Portfolio – Peru 2011, Lima. Available at: ⟨http://www.fonamperu.org⟩.

Fuhr, H., Lederer, M., 2009. Varieties of carbon governance in newly industrializing countries. J. Environ. Dev. 18 (4), 327–345.

Gertler, P.J., Martinez, S., Premand, P., Rawlings, L.B., Vermeersch, C.M.J., 2011. Impact Evaluation in Practice. The World Bank Publications, Washington D.C.. https://doi.org/10.1596/978-0-8213-8541-8.

Hamerle, A., Ronning, G., 1995. Panel analysis for qualitative variables. In: Gerhard, Anninger, Clifford, C. Clogg, Michael, E. Sobel. (Eds.), Handbook of Statistical Modeling for the Social and Behavioral Sciences. Plenum Press, NewYork.

Hancevic, P., Cont, W., Navajas, F., 2016. Energy populism and household welfare. Energy Econ. 56, 464–474.

He, J., Huang, Y., Tarp, F., 2014. Has the clean development mechanism assisted sustainable development? Nat. Resour. Forum 38 (4), 248–260. https://doi.org/10.1111/1477-8947.12055.

Hoynes, H., Miller, D., Simon, D., 2015. Income, the earned income tax credit, and infant health. Am. Econ. J.: Econ. Policy 7 (1), 172–211.

Huang, Y., Barker, T., 2012. The clean development mechanism and low carbon development: a panel data analysis. Energy Econ. 34 (4), 1033–1040.

Huq, S., 2002. Applying Sustainable Development Criteria to CDM Projects: PCF Experience. Prototype Carbon Fund, World Bank, Washington D.C., pp. 1–37.

INEI-National Institute of Statistics and Information, 2017. National Household Survey. Consultation: 12 june 2017. ⟨http://iinei.inei.gob.pe/microdatos/⟩.

Kallbekken, S., 2007. Why the CDM will reduce carbon leakage. Clim. Policy 7 (3), 197–211.

Kelejian, H.H., Prucha, I.R., 2010. Specification and estimation of spatial autoregressive models with autoregressive and heteroskedastic disturbances. J. Econ. 157 (1), 53–67. https://doi.org/10.1016/j.jeconom.2009.10.025.

Khandker, S.R., Koolwal, G.B., Samad, H.A., 2010. Handbook on Impact Evaluation: Quantitative Methods and Practices. Learning. https://doi.org/10.1596/978-0-8213-8028-4.

Lesage, J.P., 1998. Spatial Econometrics. A Companion to Theoretical Econometrics 273(Retrieved from ⟨http://books.google.com/books?hl=en&lr=&id=xs55E7FsMHMC&oi=fnd&pg=PA310&dq=Spatial+Econometrics&ots=gmeqR22yDp&sig=ugD_uxGfnM6ekZsAufZnJWbP81o⟩).

Mathy, S., Hourcade, J.C., De Gouvello, C., 2001. Clean development mechanism: leverage for development? Clim. Policy 1 (2), 251–268.

Meyer, B.D., 1995. Natural and quasi-experiments in economics. J. Bus. Econ. Stat. 13 (2), 151–161. https://doi.org/10.1080/07350015.1995.10524589.

Moratti, M., Natali, L., 2012. Measuring Household Welfare: Short versus long consumption modules. Working Paper 2012-04. UNICEF Office of Research, Florence.

Newell, P., Bumpus, A., 2012. The global political ecology of the clean development mechanism. Glob. Environ. Polit. 12 (4), 49–67.

Nicita, A., 2009. The price effect of tariff liberalization: measuring the impact on household welfare. J. Dev. Econ. 89 (1), 19–27. https://doi.org/10.1016/j.jdeveco.2008.06.009.

Olsen, K.H., 2007. The clean development mechanism's contribution to sustainable development: a review of the literature. Clim. Change 84 (1), 59–73.

Olsen, K.H., Fenhann, J., 2008. Sustainable development benefits of clean development mechanism projects: a new methodology for sustainability assessment based on text analysis of the project design documents submitted for validation. Energy Policy 36 (8), 2819–2830.

Pegg, S., 2006. Mining and poverty reduction: transforming rhetoric into reality. J. Clean. Prod. 14 (3–4), 376–387.

Pécastaing, N., 2013. L'impact du mécanisme de développement propre (MDP) sur le développement «durable» : le cas du Pérou. L'Actual. Econ. Soc. Can. Sci. Econ. 89, 39–56.

Richardson, R., Atkinson, A.B., 1970. Poverty in Britain and the reform of social security. Economica 37 (148), 432.

Sirohi, S., 2007. CDM: is it a 'win–win'strategy for rural poverty alleviation in India? Clim. Change 84 (1), 91–110. https://doi.org/10.1007/s10584-007-9271-2.

Spalding-Fecher, R., Achanta, A.N., Erickson, P., Haites, E., Lazarus, M., Pahuja, N., Tewari, R., 2012. Assessing the Impact of the Clean Development Mechanism. Report Commissioned by the High Level Panel on the CDM Policy Dialogue. CDM Policy Dialogue, Luxembourg. ⟨http://www.cdmpolicydialogue.org/research/1030_impact.pdf⟩.

Subbarao, S., Lloyd, B., 2011. Can the clean development mechanism (CDM) deliver? Energy Policy 39 (3), 1600–1611. https://doi.org/10.1016/J.ENPOL.2010.12.036.

Sutter, C., 2003. Sustainability Check Up for CDM Projects – How to assess the sustainability of international projects under the Kyoto Protocol. Berlin, WVB.

Sutter, C., Parreño, J.C., 2007. Does the current clean development mechanism (CDM) deliver its sustainable development claim? An analysis of officially registered CDM projects. Clim. Change 84 (1), 75–90. https://doi.org/10.1007/s10584-007-9269-9.

Thompson, B.S., 2013. Empirical likelihood-based inference for poverty measures with relative poverty lines. Econom. Rev. 32 (4), 513–523.

Townsend, P., 1954. Measuring poverty. Br. J. Sociol. 5 (2), 130.

UNFCCC, 2012. Benefits of the Clean Development Mechanism 2012. United Nations Climate Change Secretariat, Bonn, Germany(Available at ⟨http://cdm.unfccc.int⟩).

Wang, C., Zhang, W., Cai, W., Xie, X., 2013. Employment impacts of CDM projects in China's power sector. Energy Policy 59, 481–491. https://doi.org/10.1016/j.enpol.2013.04.010.

Watson, C., Fankhauser, S., 2009. The Clean Development Mechanism: too flexible to produce sustainable development benefits?. Grantham Research Institute on Climate Change and the Environment Working Paper No. 2. Grantham Institute, London.

Wooldridge, J., 2003. Cluster-sample methods in applied econometrics. Am. Econ. Rev. 93 (2), 133–138.

World Bank, 2017. World Development Indicators. Available at: ⟨http://data.worldbank.org/data-catalog/world-development-indicators⟩.

Zhang, J., Wang, C., 2011. Co-benefits and additionality of the clean development mechanism: an empirical analysis. J. Environ. Econ. Manag. 62 (2), 140–154.

Zhang, X., Zha, T., Zhao, Y., Qin, J., Lyv, Z., Ma, Z., Freiherr von Lueninck, B., 2017. Sustainable effects of small hydropower substituting firewood program in Majiang County, Guizhou Province, China. Sustainability 9 (6), 988.